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YOUNGER DRYAS POLLEN RECORDS FROM SVERDRUP ISLAND (KARA SEA)

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Sverdrup Island, in the Kara Sea, is currently occupied by polar desert vegetation. The analysis of Alleröd deposits indicates a climate drier than presently, with increased summer and decreased winter temperatures. The relative scarcity of distal pollen indicates that mainland source areas were located further south than at present. Younger Dryas cooling and increased dryness resulted in an increase of the proportions of *Artemisia*, *Chenopodiaceae* and *Salix* pollen, and in the extent of *Sphagnum* mosses. Preboreal time was marked by warmer, more humid conditions, with dwarf birches, *Ericales* and possibly *Alnus fruticosa*. The increased proportions of distally-derived arboreal birch pollen, coupled with the local component of the assemblages, indicates that the early Holocene represented the climatic optimum, initiated by the opening of the Arctic Ocean. Subsequent climate fluctuations were muted on Sverdrup Island, due to the development of microclimatic conditions associated with an oceanic regime. © 1997 INQUA/Elsevier Science Ltd

INTRODUCTION

The pollen evidence, although not numerous, from high latitude Siberia is of particular importance for the reconstruction of past landscape and past climates. That is particularly the case for materials related to the final Post-Glacial period and the early Holocene (Makeev and Ponomareva, 1988; Ukraintseva *et al.*, 1989; Makeev *et al.*, 1992). This evidence is particularly significant in relation to the problem of glaciation of the Arctic shelf. Judging from the present bathymetry of the Kara Sea, during the Late Pleistocene Sverdrup Island was part of the continent, the sea-level being 40–60 m below the present one during the time-span of 11–13 ka ago (Kaplin, 1975). The occurrence of erratic boulders as well as erosional-accumulative landforms on Sverdrup Island and the nearby Sergei Kirov Islands suggests glaciation. Several writers consider it to be of Late Quaternary Age (Geomorfologicheskoe, 1980; Grossvald, 1983). Others (Danilov, 1987; Danilov and Polyakova, 1989; Makeev *et al.*, 1992; Evolution of Landscapes, 1993) argue that the shelf was free of Late Quaternary ice-sheets. New pollen and radiocarbon data obtained by the present writers resulting from study of the fossil peat bog on Sverdrup Island, make it possible not only to suggest the reconstruction of the landscape-climatic setting in that region at 9700–12,000 BP, but to treat the problem of Late Quaternary glaciation of the Kara Sea shelf from a different angle.

Field investigations and the collecting of samples within were carried out in July–August 1992 by F.A. Romanenko (Moscow State University) the framework of the Arctic expedition of the Institute for Evolutionary Morphology and Animal Ecology of the Russian Academy of Sciences. The pollen analyses and the interpretation of the results were made by A.A. Andreev (Institute of Geography, Russian Academy of Sciences) and P.E. Tarasov (Moscow State University). Radiocarbon analysis was carried out by L.D. Sulerzhitsky (Institute of Geology, Russian Academy of Sciences). Botanical materials were kindly provided by a participant of the expedition, Yu. P. Kozhevnikov (Institute of Botany, Russian Academy of Sciences).

Sverdrup Island (74°30′ N, 79°30′ E) is located on the Kara Sea shelf, at a distance of 110 km off the coast (Fig. 1), and belongs to the Yamal-Gydan geomorphic sub-province of the Kara Sea shoal, directly north of the Ob mouth and Yenisey Bay (Dibner and Zakharov, 1970). The island was discovered on 18 August 1893 by F. Nansen in the course of the famous Fram expedition. The first landing was made in August 1933 from the ice-breakers Sibiryakov and Rusanov. This party included Gakkel and Vlodavets who made the initial description of the relief and geology of the island (Vlodavets, 1933).

The total area of the island is 70 km^2, about a third being taken up by sand spits, less than 2 m high a.s.l. The maximum height, 33 m a.s.l., is recorded in the central part of the island. The island's surface forms a terraced accumulative plain, intensively eroded by ravines. The island is formed by Upper Cretaceous deposits of continental origin, flanked by recent marine sediments. The overlaying Quaternary deposits consist of boulders and pebbly–gravelly sand and loam (Geomorfologicheskoe, 1980; Dibner and Zakharov, 1970). The buried peat-bog is found in the northern part of the island, at the altitude of 7–8 m a.s.l., 6 m inland from the coast.

Mean July temperature on the island is 0.4–3.4°C, and that of January is −26 to −28°C. The annual precipitation is 200–300 mm. The frostless period lasts 20–30 days. Due to the severity of climate, the vegetation of the island is of the polar desert type. The vascular flora, poor in diversity, includes 34 taxa belonging to the following families: *Cyperaceae, Poaceae, Ranunculaceae, Juncaceae, Polygonaceae, Caryophyllaceae, Rosaceae, Saxifragaceae, Brassicaceae, Salicaceae, Papaveraceae* and *Scophularaiceae*. Mosses are represented by 27 species and lichens by 33 species.

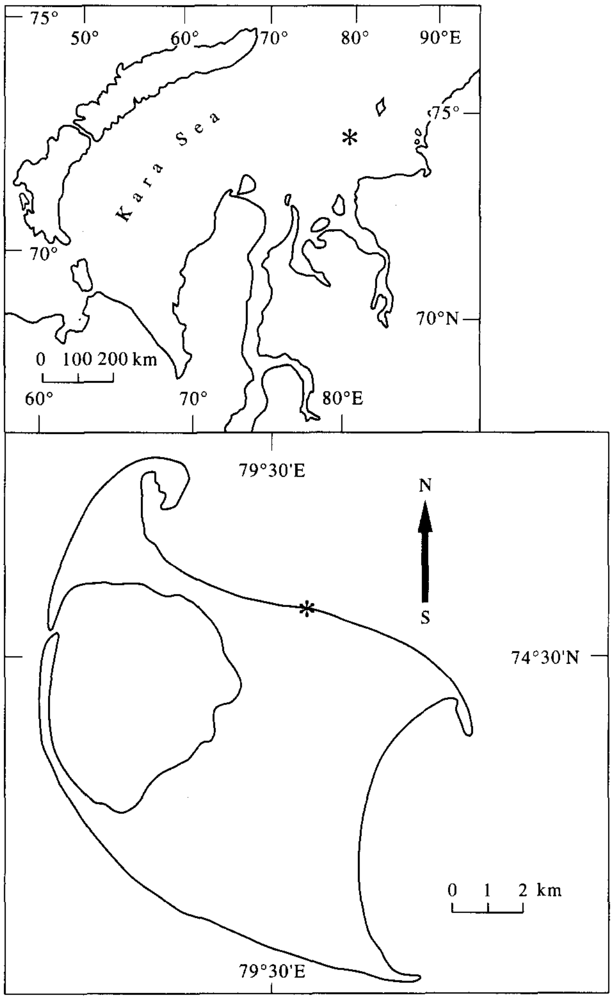

FIG. 1. Geographical position of Sverdrup Island and location of studied section.

Case study

The samples for pollen analysis and radiocarbon dating were collected from the undisturbed 2.2 m thick section of a coastal cliff, at 10 cm intervals (Fig. 2). The samples were processed in the Laboratory for The Study of Recent Deposits and Pleistocene Palaeogeography of the Moscow State University according to the (Grichuk and Zaklinskaya, 1948) method, and studied under the Neovar 2 microscope with 400× magnification. The samples of peat were extremely rich in pollen. Those of the underlaying and overlaying sand contain practically no Quaternary grains (2–3 grains per sample). The only exception was the samples from 10 cm below surface, each of which contained 25–30 *in situ* grains. It was decided to exclude from counting samples poor in pollen with numerous redeposited grains. The average number of pollen in counted samples of peat is 300. The pollen diagram was plotted with the use of Tilia Graph Software.

The samples for radiocarbon dating were collected from the buried peat (0.3–0.85 cm) at 10–15 cm intervals. The samples for botanical analysis were taken from the same levels. The botanical analysis was carried out in the Botanical Laboratory of the "Torfgeologiya" Industrial Enterprise. Radiocarbon measurements were conducted at the Laboratory for Isotope Geochemistry and Geochronology of the Institute of Geology, Russian Academy of Sciences, by means of β-counting on liquid scintillation counters from benzene converted from the alkaline extraction (Arslanov, 1987).

Results and discussion

The 1.3 m thick series of sand and loamy sand with inclusions of buried cavern-load ice at the base of the section (Fig. 2) contains but few grains of Quaternary pollen, on which evidence definite conclusions about its age cannot be drawn. The presence of relatively numerous redeposited Mesozoic pollen suggests that the sand is of aeolian origin, genetically related to the Upper Cretaceous bedrock. One may also suggest that the

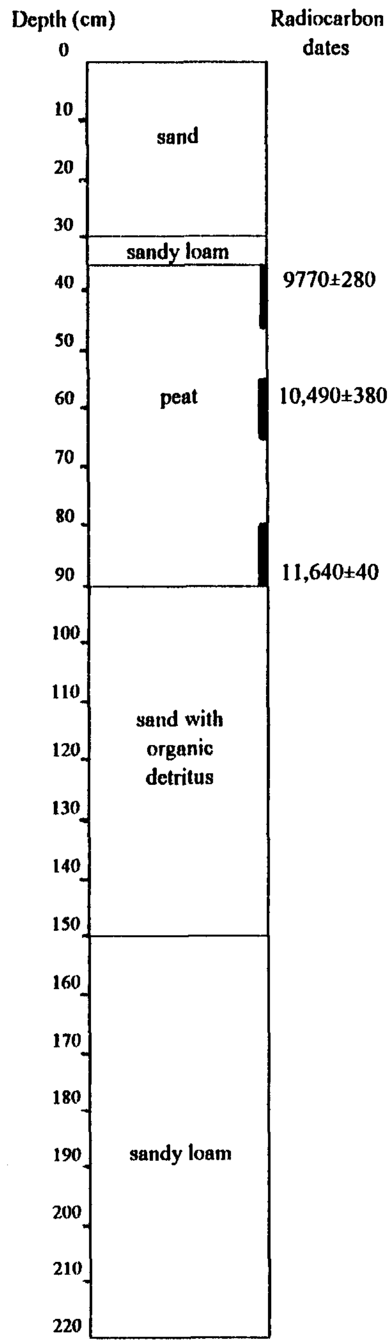

FIG. 2. Lithology and radiocarbon dates from the Sverdrup Island section.

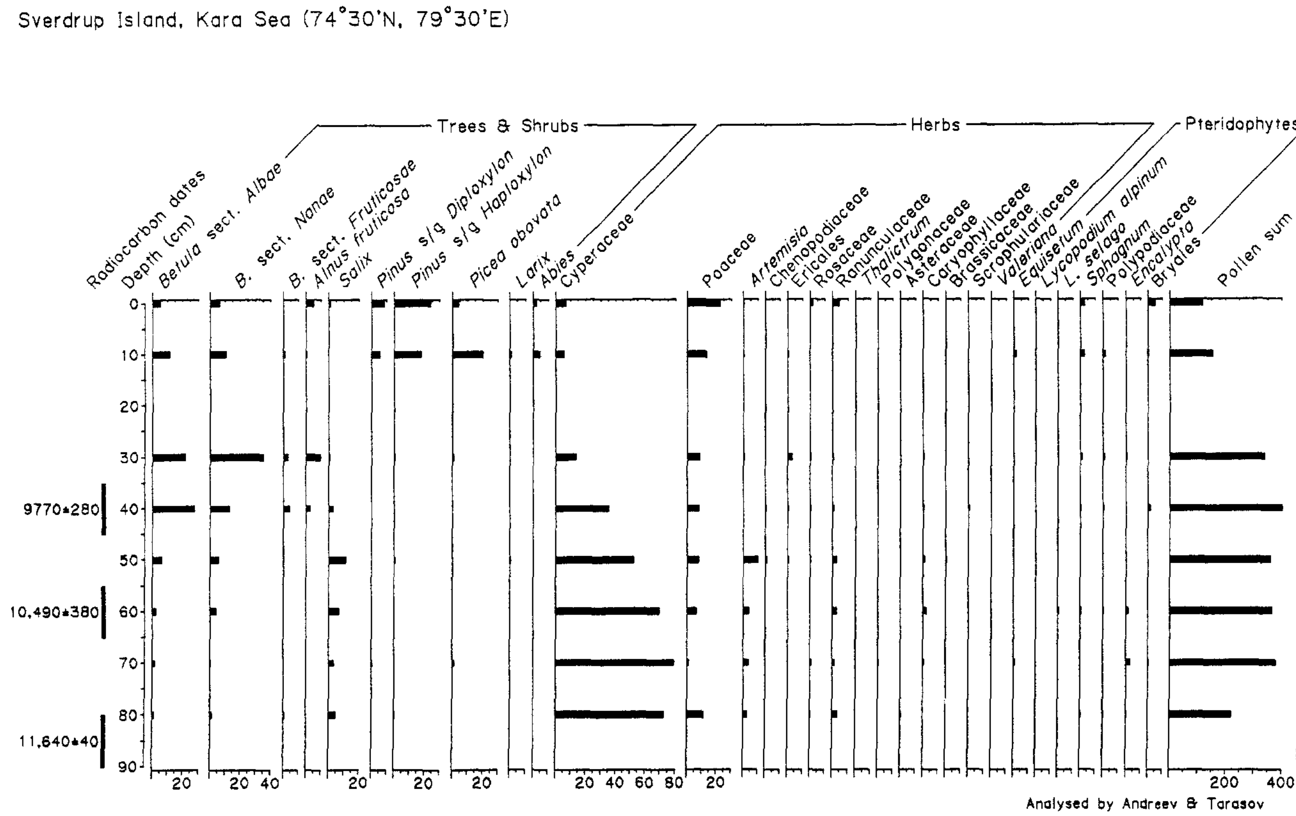

FIG. 3. Pollen diagram of the Sverdrup Island section.

formation of ice wedges corresponds to the maximum stage of Upper Pleistocene cooling, when the aeolian and permafrost processes were active on the exposed shelf in an environment of extremely cold continental climate. Hence, our data are well in accord with the conclusion about the lack of a Late Pleistocene ice sheet in northwestern Siberia.

The overlaying layers (0.3–0.85 m) consist of buried peat. The sample from its lower (0.8–0.85 m) portion yielded a radiocarbon age of 11,640+40 (GIN-7625), indicating that the formation of sedge peat had started in the Alleröd. Judging from the composition of pollen (Fig. 3), the communities were dominated by the present-day tundra texa: *Bryales*, *Poaceae*, *Cyperaceae*, *Salix*, *Ranunculaceae*, *Rosaceae*, *Polygonu*, *Caryophyllaceae* and *Valeriana*, which coexisted with the steppeic associations with *Artemisia*, *Chenopodiaceae*, *Thalictrum* and *Asteraceae*. Rare grains of spruce, pine, shrub and arboreal birches were probably wind transported. The pollen of dwarf birch (*Betula* sect. *Nanae*) is an exception: growing on the surface of the peat-bog (as evidenced by the finds of macro remains) they had a very low pollen productivity. The low content of the pollen of long distance influx (several times lower than in the surface sample) proves that their source areas were much further away from the island than they are now.

The Alleröd climate was much drier than presently. The summer temperature exceeded the present value, while the winter temperature was lower than today. The accumulation of peat starting in the Alleröd is definitely indicative of a significant amelioration of climate and the lack of an ice-sheet on the island at the final stage of the Late Glacial period.

The Younger Dyas cooling had a considerable effect on the pollen spectra, where the proportion of *Artemisia*, *Chenopodiaceae* and *Salix* increased significantly. The botanical composition of peat changed, indicating an increased importance of green mosses in the mire vegetation. The sample from 0.55 to 0.65 m in depth yielded a radiocarbon age of 10,490±380 BP (GIN-7626). The increase in *Artemisia* and *Chenopodiaceae* communities are indicative of increased dryness of climate. At the same time, the increased amount of willows and dwarf birch (*Betula* sect. *Nanae*) pollen as well as the finds of macro-fossils of dwarf birch in the peat proves the enhancement of shrub formation on the surface of the peat-bog, equally indicative of a less humid environment. The cooling and increased dryness are also indirectly seen in the lower rate of peat formation and common occurrence of distally transported pollen of birches (sect. *Albae*).

Early Preboreal warming was marked by an abrupt change in the composition of pollen spectra, dominated by arboreal and shrub species with steppic species nearly totally disappearing. The botanical composition of peat remained basically unchanged. Notable is the disappearance of birch, probably following the increased wetness, and the disappearance of shrubs from the surface. Two radiocarbon dates: 9770±280 BP (GIN-7627) from the upper layer of peat (0.35–0.45 m), and the above-mentioned one from the lower level: 10,490±380 BP (GIN-7626), suggest that this warming was manifested throughout northern Eurasia at ca. 10,300 BP (Khotinsky, 1977).

The vegetation of Sverdrup Island at that time was typical of the present-day southern tundra, with the participation of dwarf birches, *Ericales* and possibly *Alnus fruticosa*, which do not grow on the island now. In spite of the high content of birch pollen, arboreal birches were not growing in the immediate vicinity of the island, yet the northern limit of their distribution at that time was extended considerably further to the north as compared with its present position. All this evidence clearly suggests that the climate in the Early Preboreal was much milder than now. The Early Holocene climatic optimum in the high latitude Arctic was acknowledged by several scholars (Lozhkin, 1987; Makeev and Ponomareva, 1988; Ukraintseva *et al.*, 1989; Ukraintseva, 1990; Nikolaev and Kolokolov, 1992; Ritchie *et al.*, 1983; Clague and Mathews, 1989). The main cause of this warming becoming the optimal one in this area of the Arctic, was the rapid rise of sea-level during the Boreal period, resulting in the transformation of the dry area with an intensely continental climate into insular and coastal terrain with spatially discontinuous climatic conditions.

Hence, the Early Preboreal warming was manifested in the present-day coastal and insular areas as the thermal maximum under conditions of still sufficiently continental climate. All subsequent Holocene warmings took effect under conditions of predominantly oceanic climate. Due to the moderating effect of the cold Arctic Ocean, the Late Atlantic climatic optimum has had a much lesser impact on the Arctic environment.

The formation of peat ceased in the middle Preboreal. The overlying aeolian sand with ice-wedge pseudomorphs filled in by the loamy material is extremely poor in pollen, and no assessment of landscape and climate change is possible.

The sample from the depth of 10 cm contains few pollen grains which belong to taxa of distal influx (*Pinus*, *Picea*, *Betula*, *Alnus*) as well as the local flora (*Poaceae*, *Salix*, *Ranunculaceae*, *Rosaceae*). This composition of pollen spectra and the concentration of taxa of distal influx is usual for the High Arctic (Krenke and Fedorova, 1961; Kalugina *et al.*, 1979; Bourgeois *et al.*, 1985; Van der Knaap, 1990; Andreev, 1992) and adequately reflects the scarce vegetation of the Arctic Tundra.

CONCLUSIONS

Based on the palynological investigation of the buried peat and the reconstruction of the vegetation on that basis, three stages in the evolution of vegetation and climate may be distinguished. The first stage, which is dated to the Alleröd, features a mild and wet climate. The vegetation was dominated by typical tundra associations, with the occurrence of steppe dominated coenoses. The second stage (Younger Dryas) corresponds to the cold and dry climate. The third stage was the climatic optimum in this region, as well as for all other coastal areas in the High Arctic. This stage which corresponds to the global warming of climate at ca. 10,300 BP, was caused by a relatively low position of the Arctic Ocean, determining the prevalence of the continental climate. This made it possible for the vegetation typical of the present-day shrub-tundra to thrive in that area.

The accumulation of peat, which started at ca. 11,500 BP under the conditions of global amelioration of climate, stopped at about 9600 BP. The main cause was the change of climate, primarily resulting from the rapid rise of sea-level. The lowering of summer temperature and the shortening of the vegetation period adversely affected the vegetation of Sverdrup Island, leading to the disappearance of dwarf birches (sect. *Nanae*), as well as *Ericales* and *Alnus fruticosa*. The island's vegetation acquired its present day aspect of Arctic desert.

Our evidence is clearly indicative of the absence of any Late Sartanian ice-sheet either in the north of West Siberia or on the Kara Sea shelf. Coastal lowlands and vast areas of dry shelf were the arena of permafrost and aeolian activities.

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